

A Summer at Fermi National Laboratory

In which one math teacher struggles
to do pretty much anything...

The Standard Model

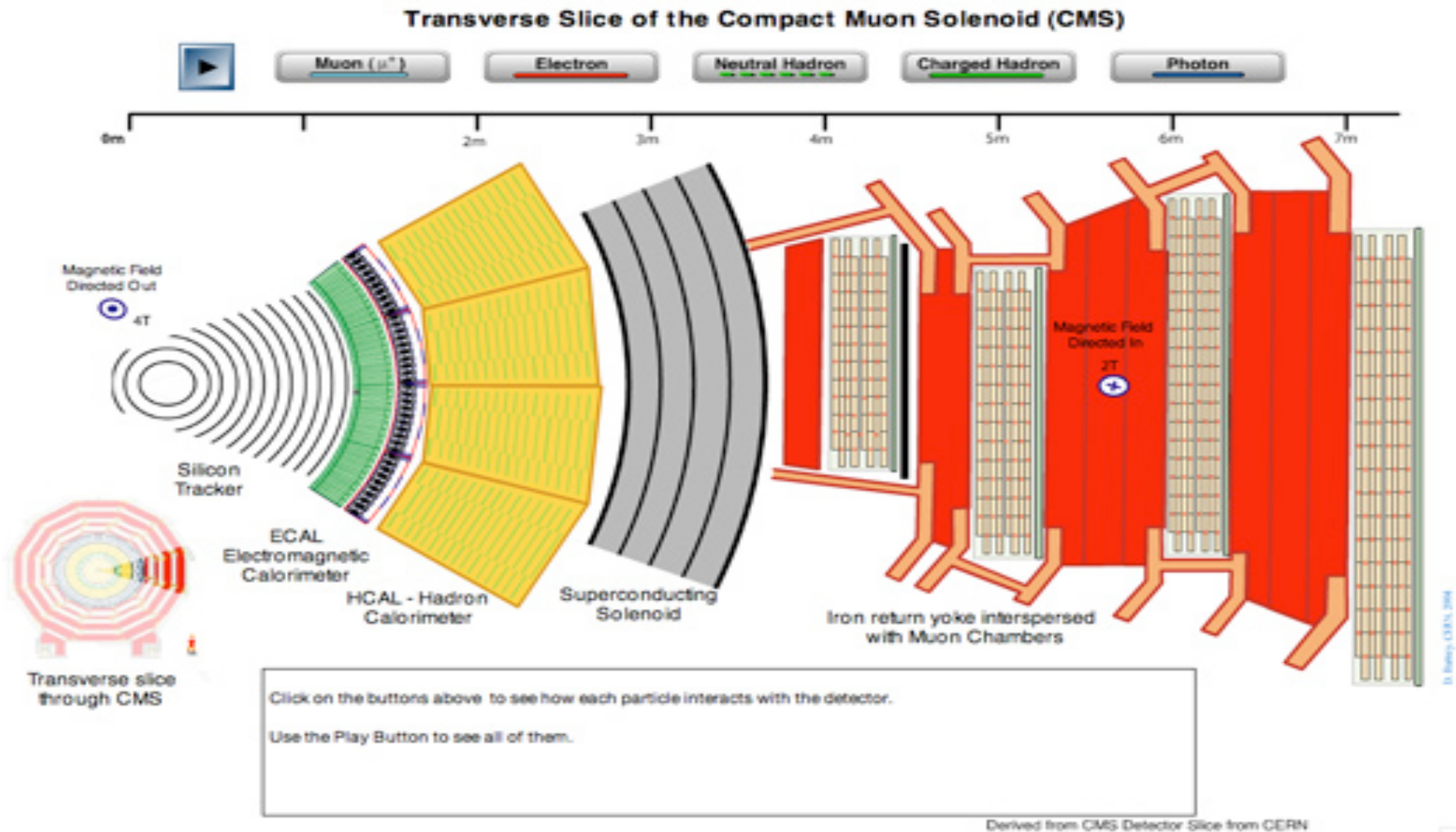
- Three Generates of Matter.
- Mass, Charge, Forge, spin

Three Generations of Matter (Fermions)			
	I	II	III
mass→	2.4 MeV	1.27 GeV	171.2 GeV
charge→	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$
spin→	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
name→	u up	c charm	t top
Quarks	4.8 MeV $-\frac{1}{3}$ $\frac{1}{2}$ d down	104 MeV $-\frac{1}{3}$ $\frac{1}{2}$ s strange	4.2 GeV $-\frac{1}{3}$ $\frac{1}{2}$ b bottom
	<2.2 eV 0 $\frac{1}{2}$ ν_e electron neutrino	<0.17 MeV 0 $\frac{1}{2}$ ν_μ muon neutrino	<15.5 MeV 0 $\frac{1}{2}$ ν_τ tau neutrino
	0.511 MeV -1 $\frac{1}{2}$ e electron	105.7 MeV -1 $\frac{1}{2}$ μ muon	1.777 GeV -1 $\frac{1}{2}$ τ tau
Leptons			
			91.2 GeV 0 0 1 Z ⁰ weak force
			80.4 GeV ± 1 1 W [±] weak force
			Bosons (Forces)

CMS Experiment

- The CMS detector is designed to detect electrons, muons, tau leptons, photons, and quark jets.
- The idea is that we will learn more about the fundamental physics of the universe because based on the SM everything in the universe is hopefully composed of these particles that we can detect, or it will create an experimentally accessible signature related to things that we can detect.

The CMS Detector



What questions might we ask?

Where did any of the parts of the model originate.

Why does the model have the structure that it has?

Why do the particles have the masses that they have?

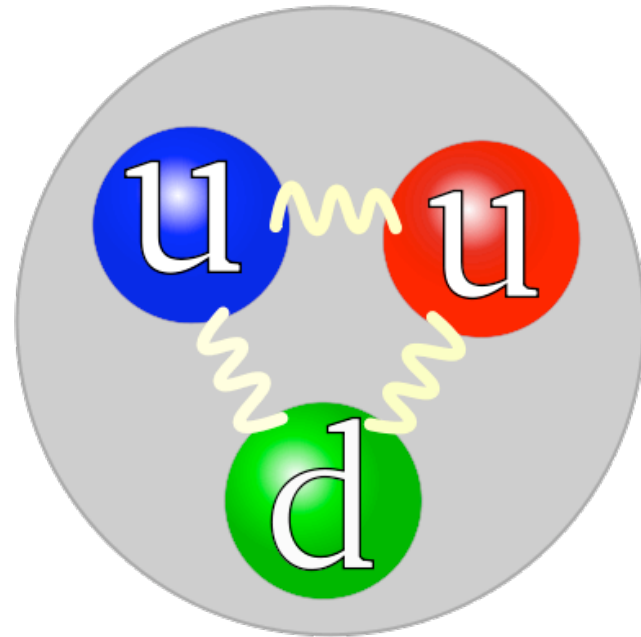
Why do particles have mass at all? Does the Higgs boson really exist?

Why is there more matter than antimatter in the universe?

What's the deal with dark matter and dark energy?

What did we actually Study?

- The structure of the proton.
- Classically we have two up and one down quark.



The Sad Quantum Mechanical Truth

- We have a probability that we'll have this combination of quarks, or one of several other combinations.
- Why?
- Mostly because of those pesky gluons...
- $g \rightarrow qq$ where g is a gluon and q and \bar{q} are a quark/anti-quark pair.

It gets worse...

- What we're studying is the parton distribution function. What this means is that we wish to know something about the momentum fraction of a quark within a proton when momentum is transferred to the other proton.
- (Why are we talking about momentum transfer rather than collision? Classically they are the same)

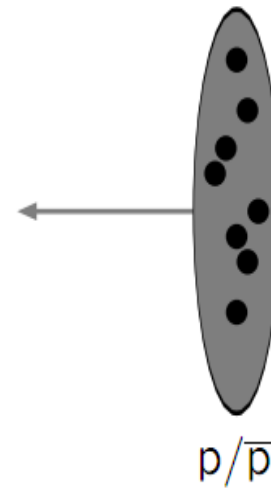
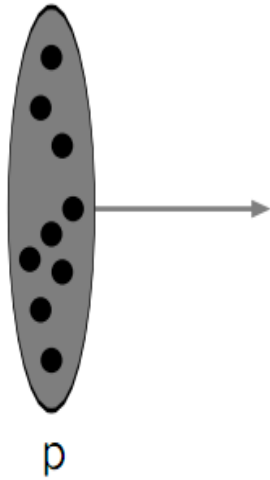
Heisenberg is a Jerk

- $\Delta x \Delta p \geq \hbar/2$
- So not only do we not know exactly what is inside the proton. When we think that they are “colliding” we really don’t even know where they are. What we know is that there is probabilistic way of discussing interaction points and momentum transfers.

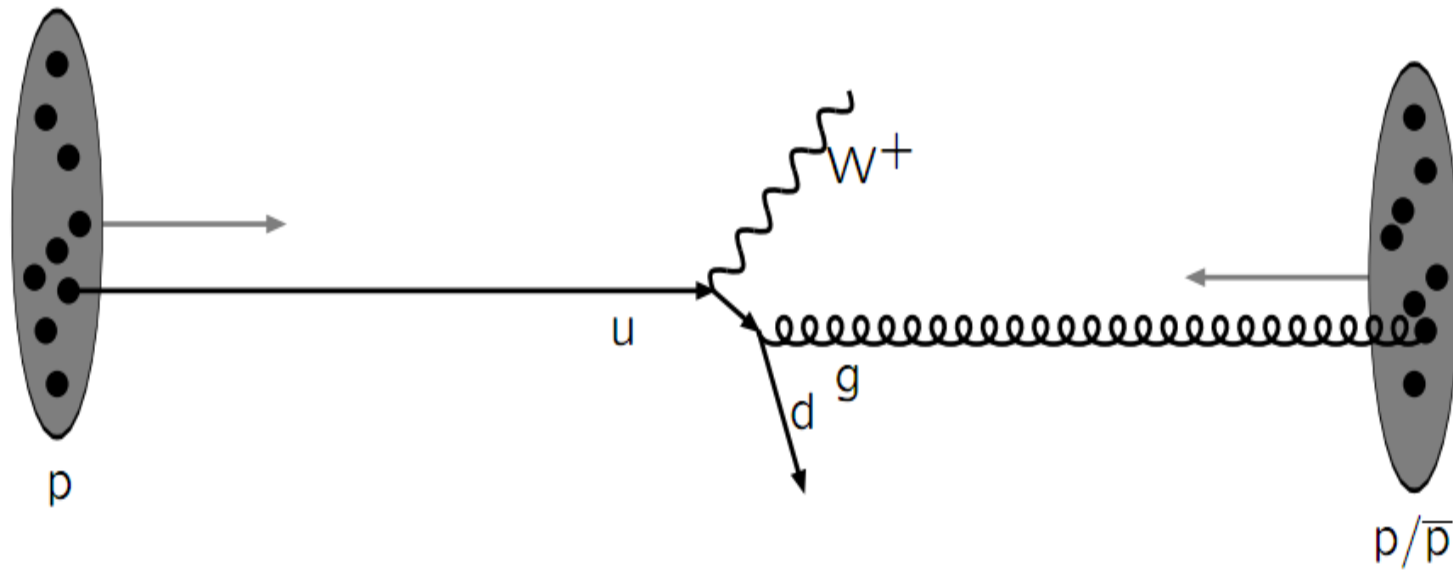
Now seems like a good time to quit
physics and have pie

- True...
- But if we were going to forgo pie for a moment what else might we do?
- A question that we might ask is: What can we figure out about the what is inside of the proton based on what happens at the moment of momentum transfer?

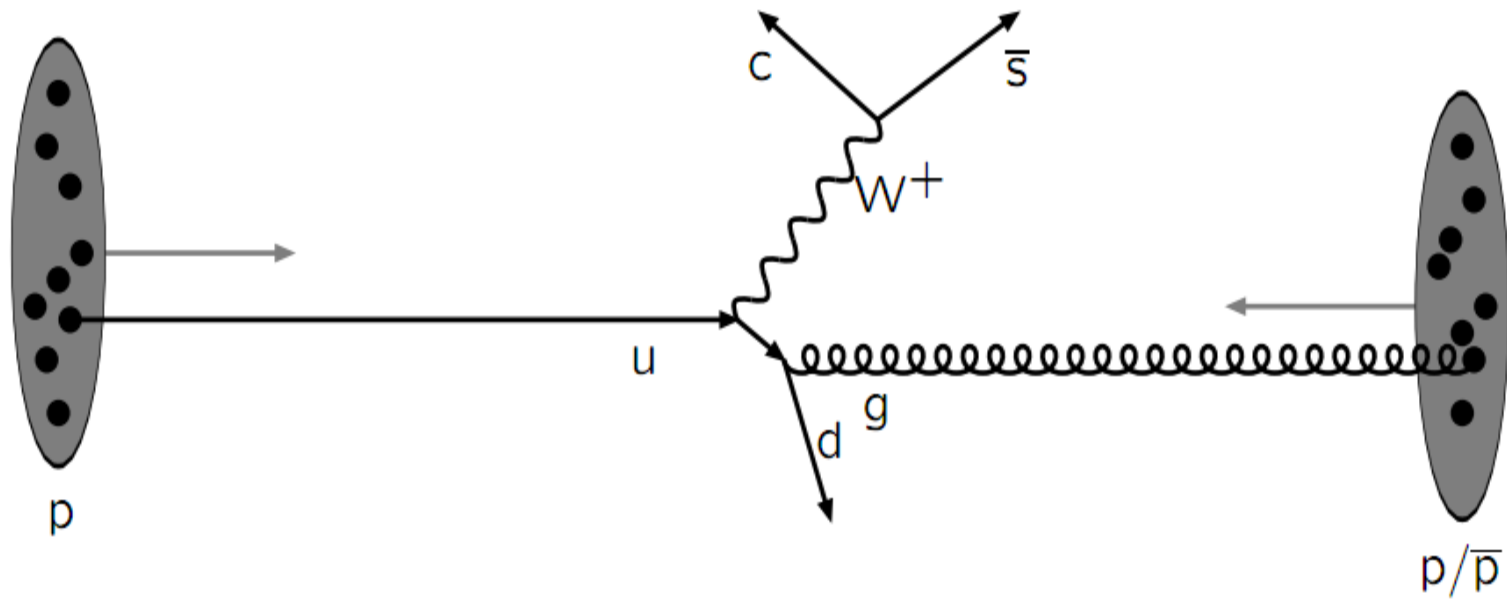
Inside the detector



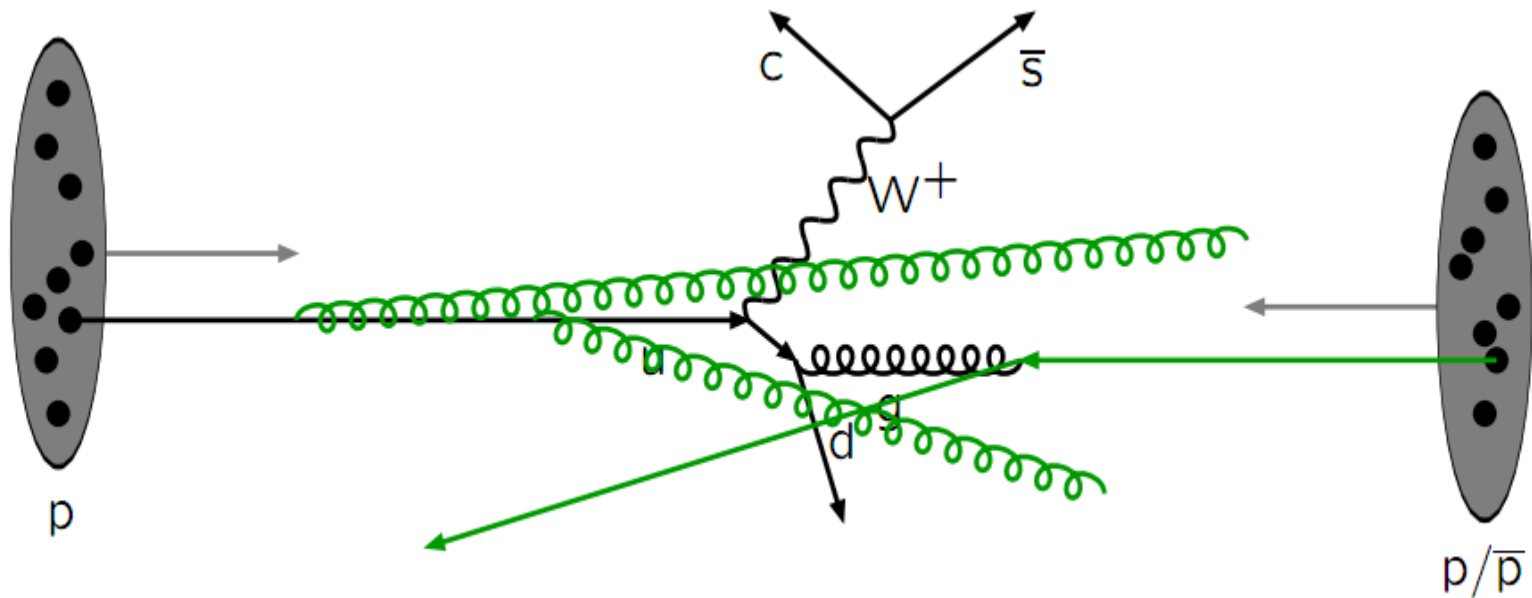
Hard Subprocess



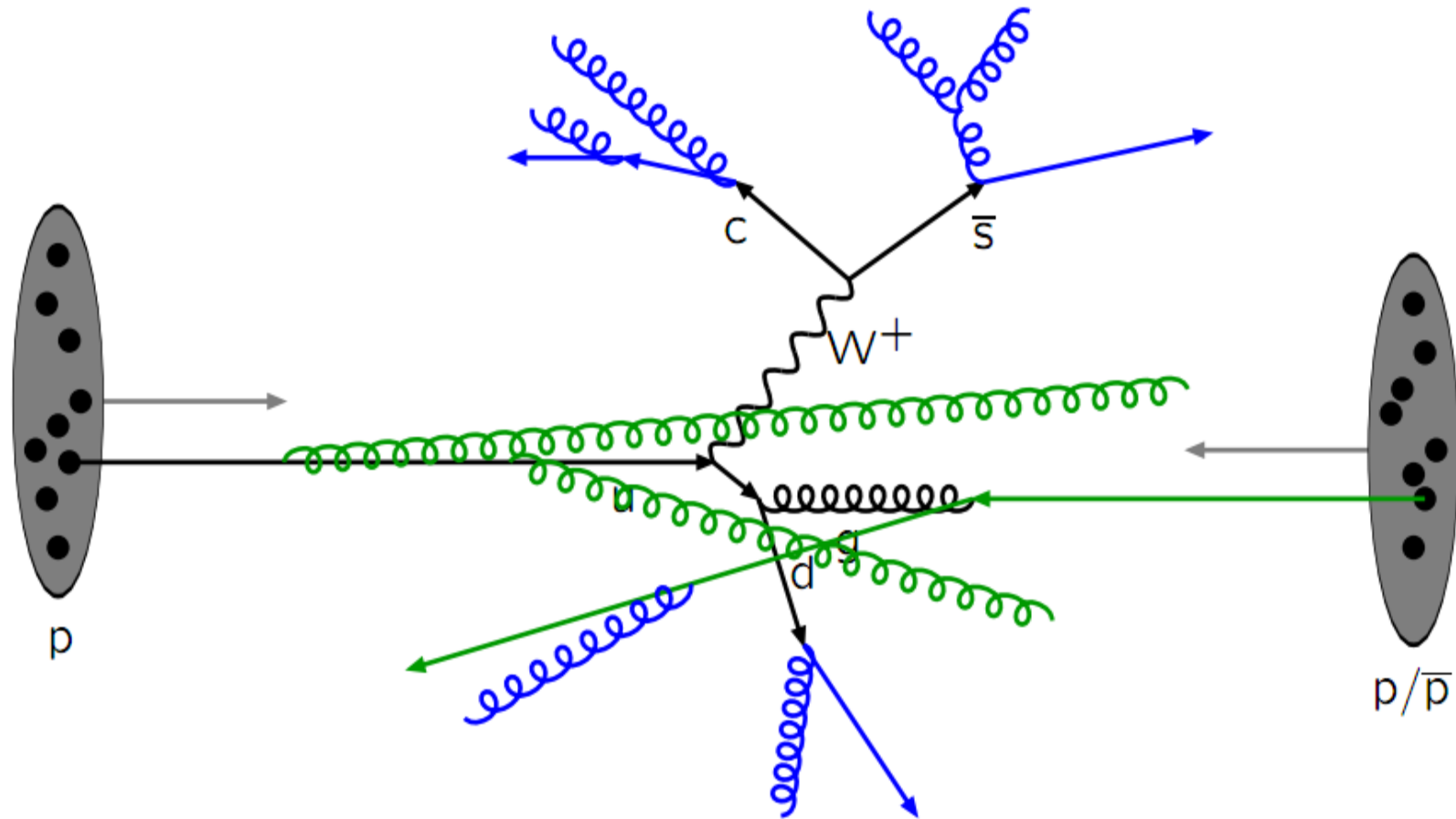
Resonance Decays



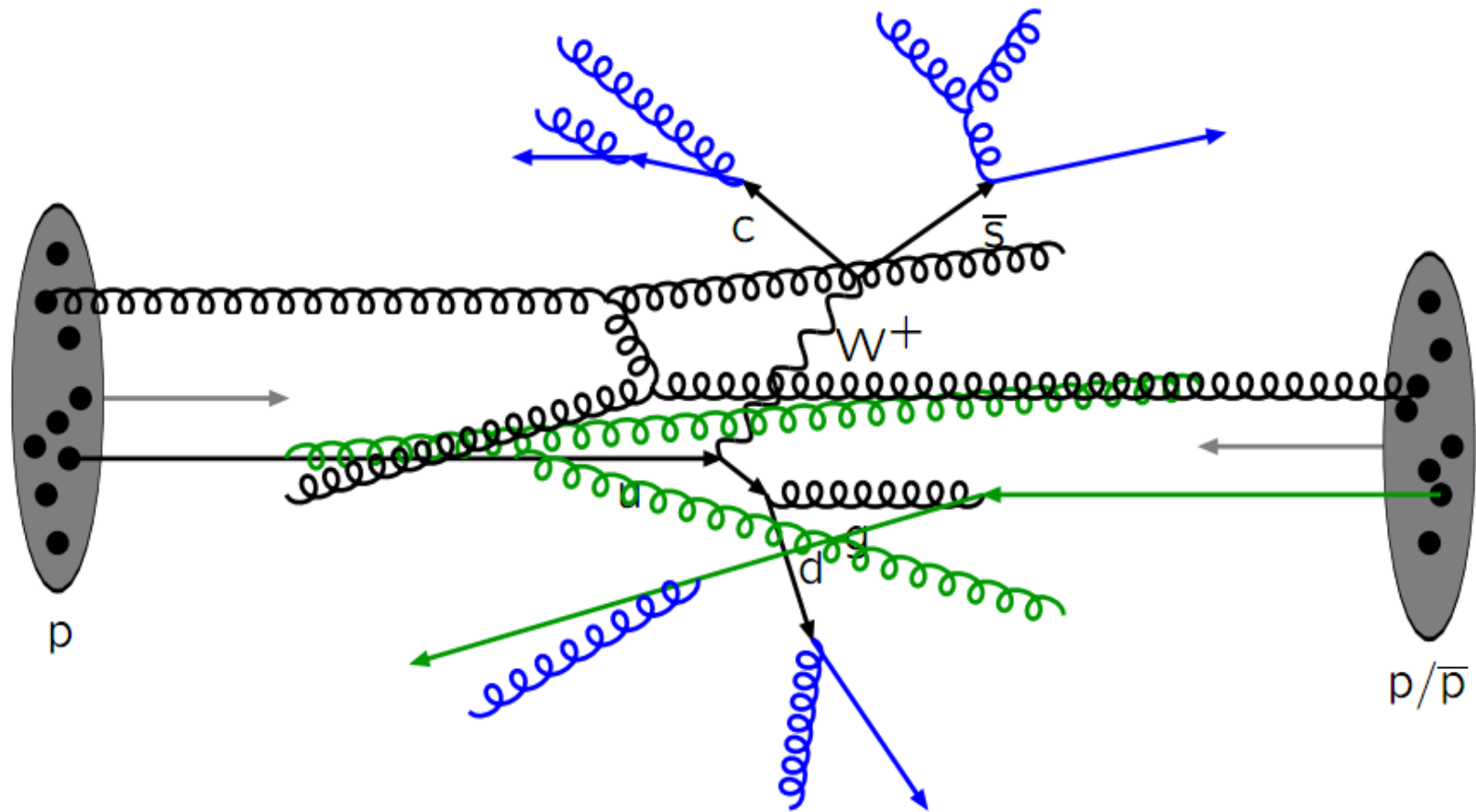
Initial State Radiation



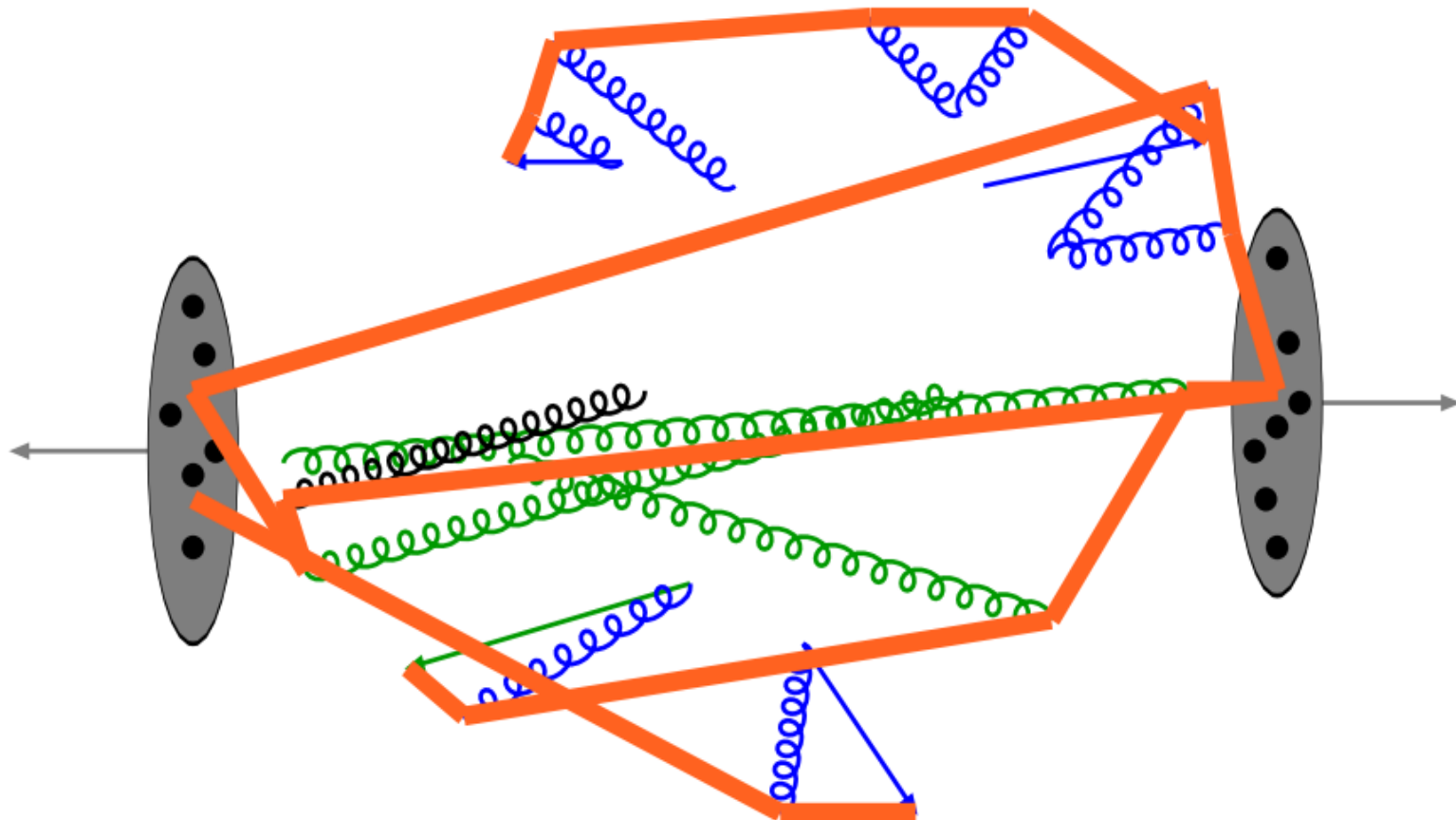
Final State radiation



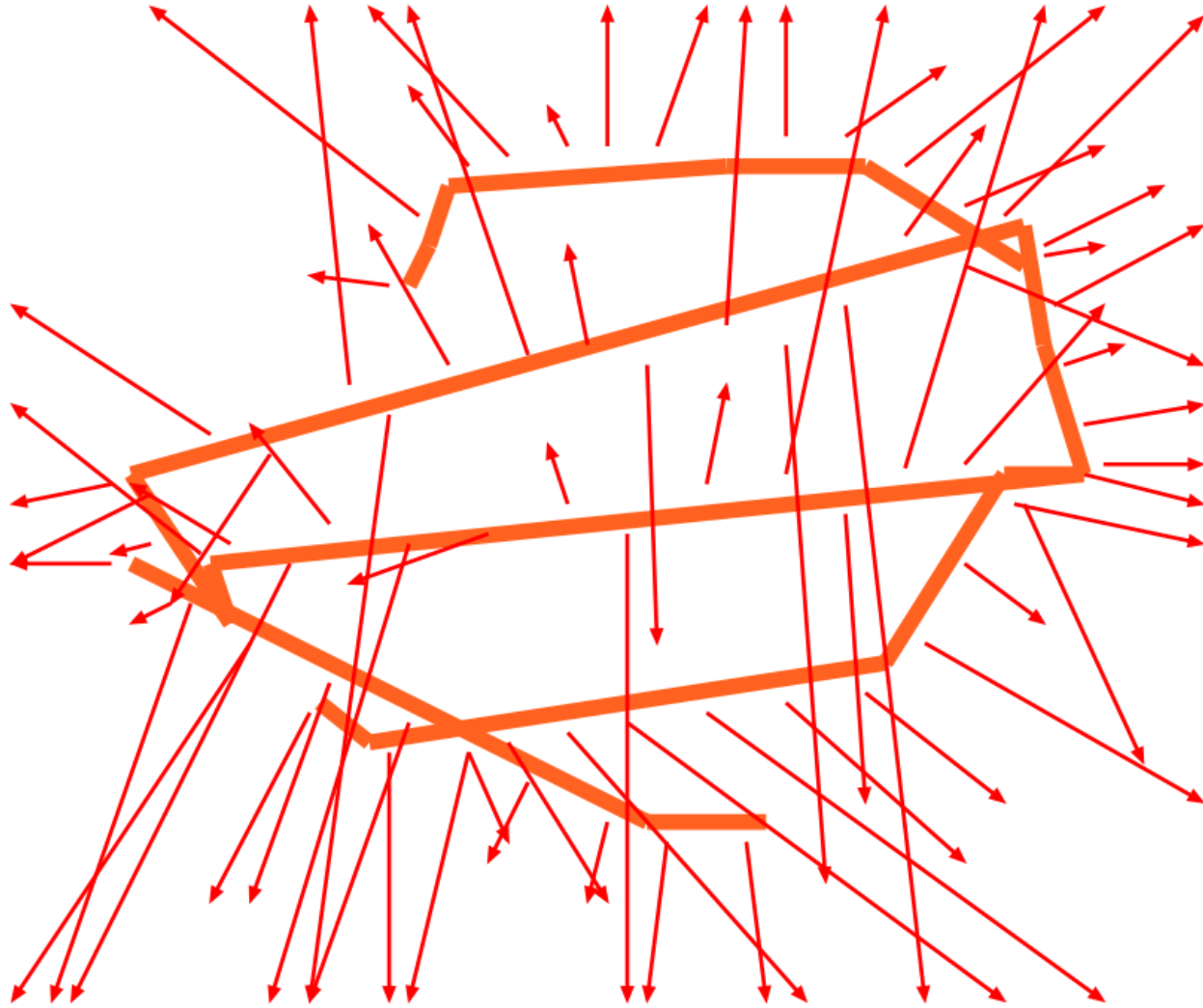
Multiple parton interactions



Everything is connected by color
confinement strings

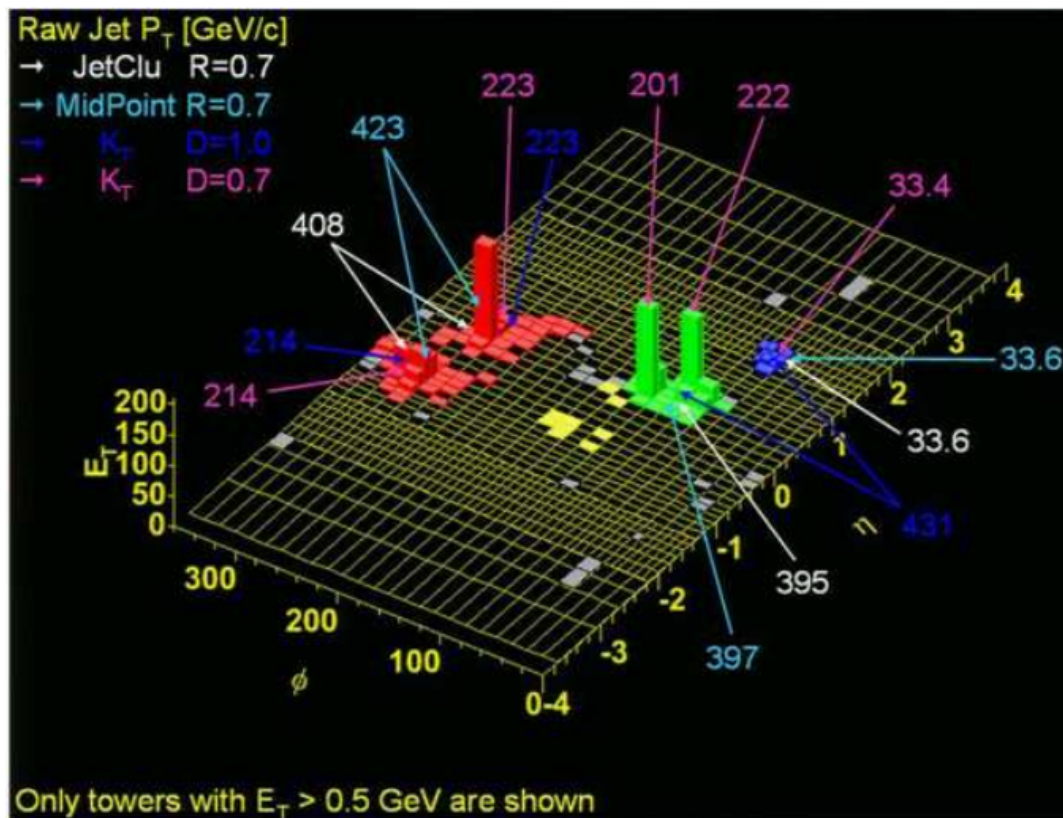


Strings Fragment to produce hadrons



What we seen in the detector

Parton Showers



- Final-State (Timelike) Showers
- Initial-State (Spacelike) Showers
 - Matching to Matrix Elements

A New Hope

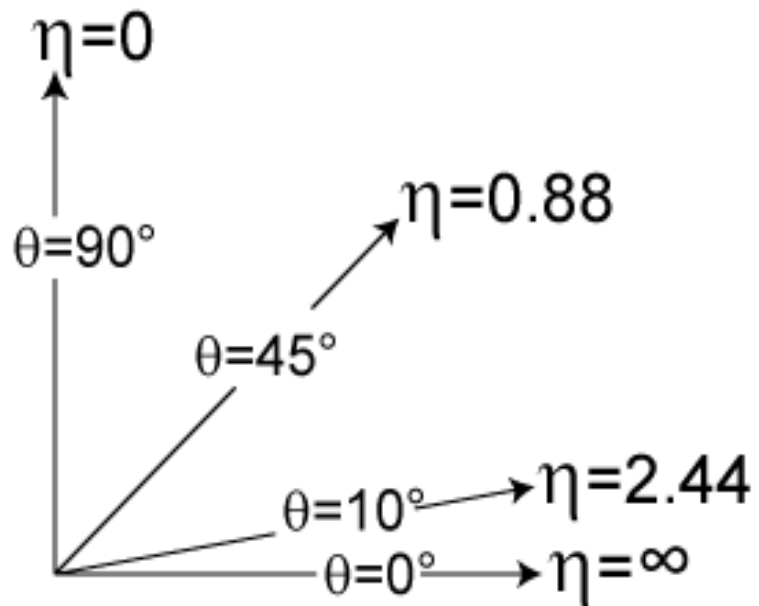
(Obligatory Star Wars reference)

- Answer: We can learn about the u/d ratio and the sea antiquark densities!
- Consider the process: $u + d \rightarrow W \rightarrow \mu \nu$
- Sadly, due to the neutrino, the boson momentum is not experimentally accessible
- What we can access is lepton charge asymmetry

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \rightarrow \ell^+ \nu) - d\sigma/d\eta(W^- \rightarrow \ell^- \bar{\nu})}{d\sigma/d\eta(W^+ \rightarrow \ell^+ \nu) + d\sigma/d\eta(W^- \rightarrow \ell^- \bar{\nu})}$$

What does that mean?

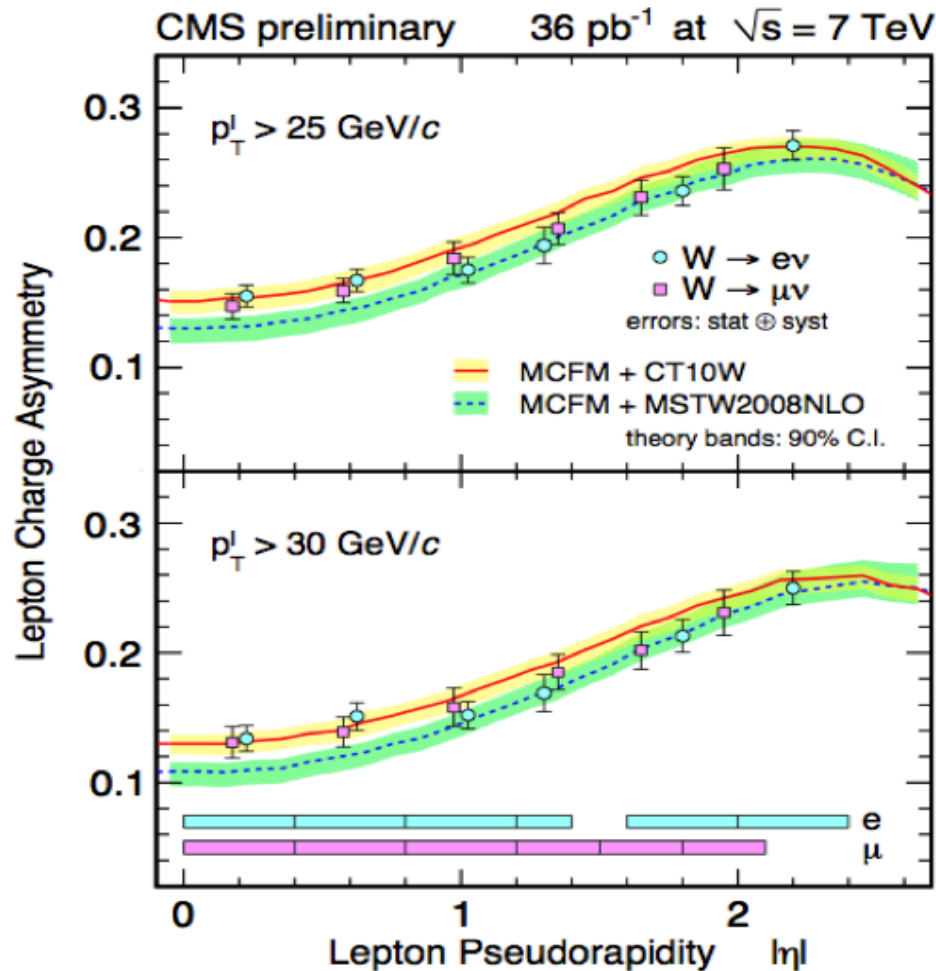
- What is pseudorapidity?
- $\eta = -\ln[\tan \theta/2]$



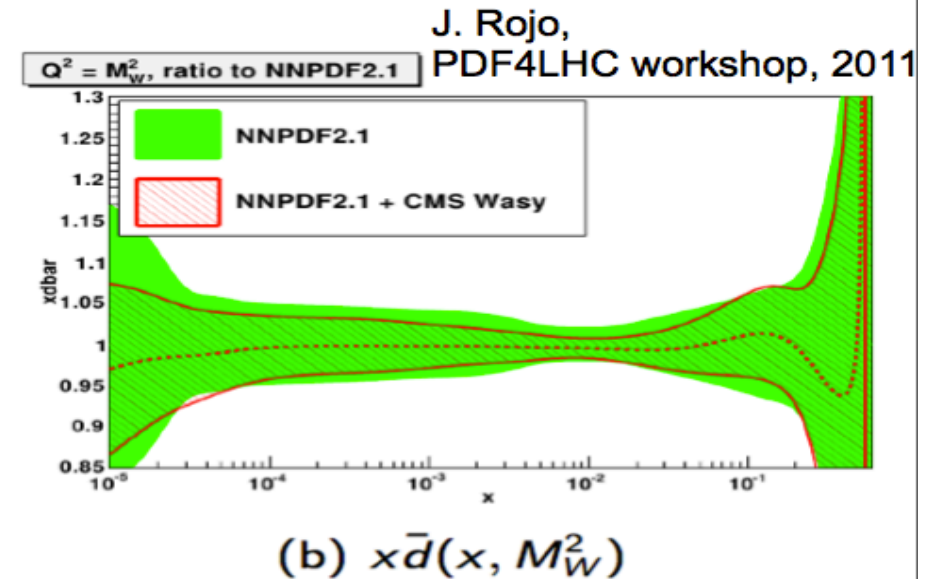
So what's the relationship?

- The lepton charge asymmetry and the W boson charge asymmetry have both been studied at the Tevatron and the D0 experiment. However, predictions don't match the current Parton Distribution Function models (What's a PDF?)
- A PDF is a probability density for finding a particle with a specific momentum fraction at momentum transfer.

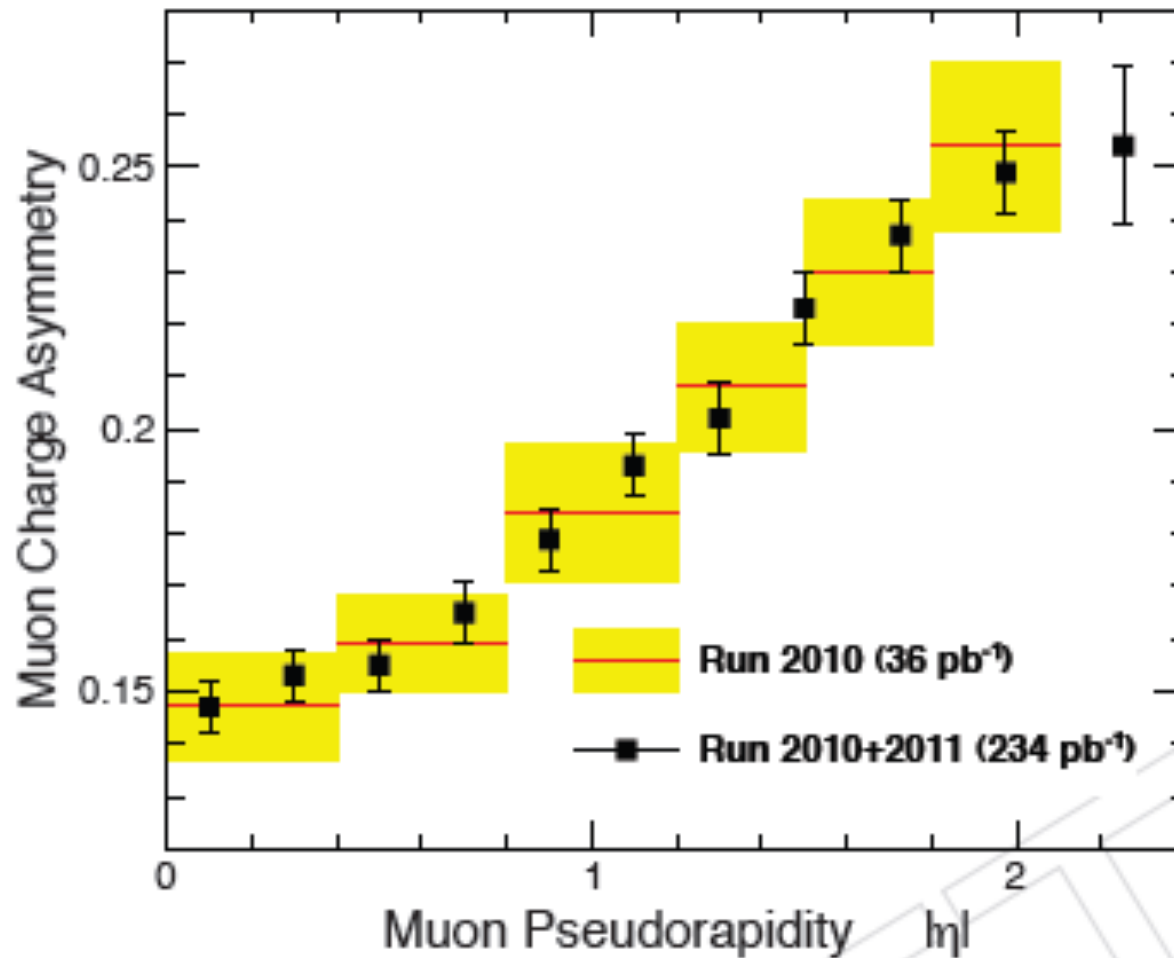
So What do we know now?



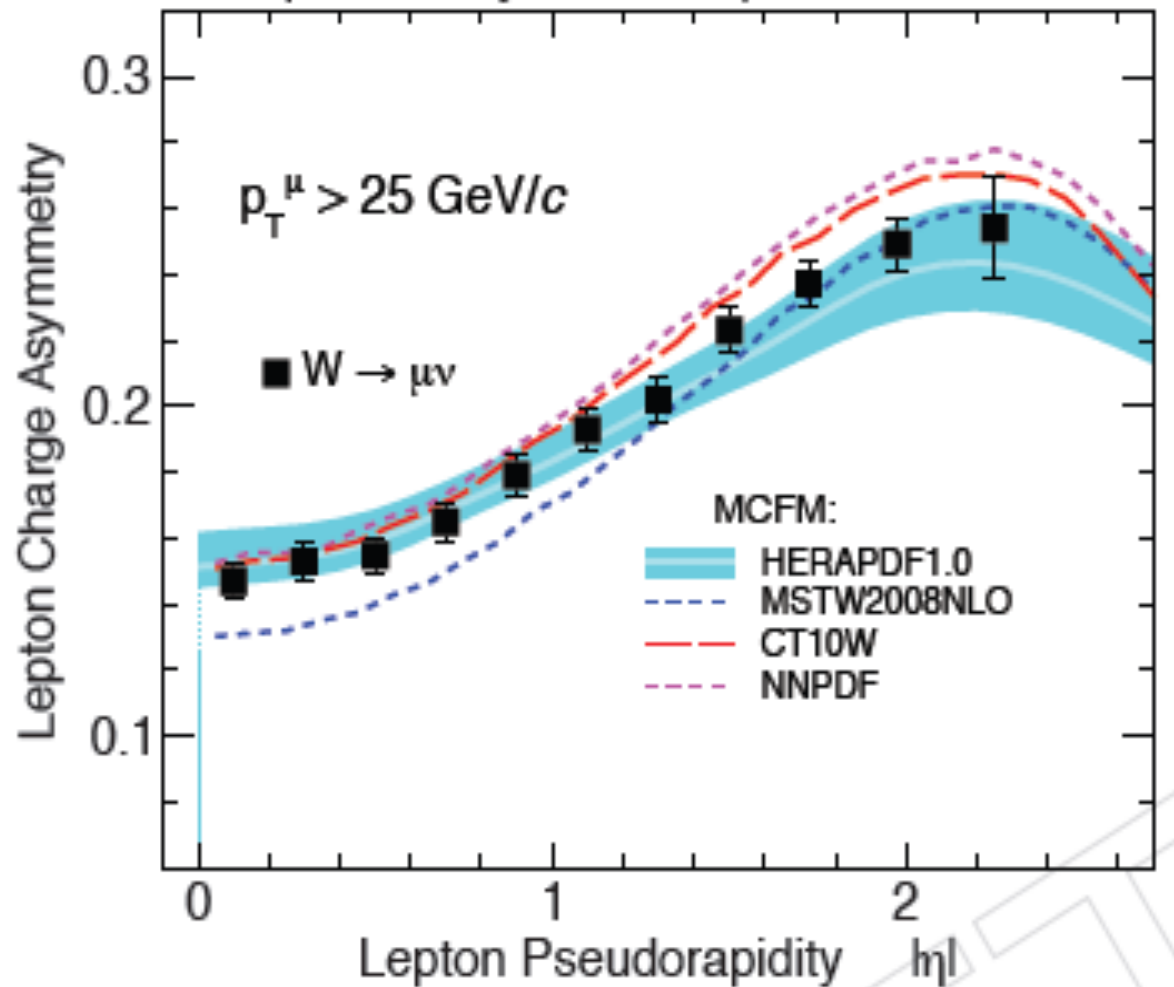
- ◆ Prompt feedbacks from PDF global fit community.
- ◆ Improve our understanding of sea quark already!



A Comparison of Results



The Theorists have some work to do



What does this mean?

- We can now constrain future PDF models because our data set is much bigger this year compared to last.